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VERIFICATION OF TRANSLATION

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I verify that the attached English translation is a true and correct translation made by me of the attached specification in the German language of International Application PCT/AT00/00236;

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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APPARATUS FOR ADDING GAS TO A MOLTEN PLASTIC MATERIAL

Processes for the production of foam structural parts of thermoplastic materials were already being developed in the middle of the Sixties. The use of those processes resulted in moldings with a more or less compact outer skin and a closed-cell foamed core. An aspect which is particularly attractive in terms of uses is the possibility of saving weight and the increase in rigidity, with the same component weight.

Basically the known processes differ on the following points:

- use of chemical or physical propellant,
- filling the tool with molten material, with or without a gas counterpressure,
- mode of operation with or without a mold cavity variation for the foaming process, and
- use of a tool cooling system or a combined heating-cooling system.

In the traditional TFM process (Thermoplastic Foam injection Molding Process) in particular molten thermoplastic materials provided with chemical propellants are injected at high speed. The tool cavity is only partially filled - the remaining filling or shaping of the component geometry is implemented by the expansion pressure of the propellant. As chemical propellants only apply foaming pressures of up to 30 bars the process is limited in terms of wall thickness and flow paths which can be traversed as well as the shaping of more complex component geometries.

Chemical propellants or foaming agents are substances which break down under the effect of heat and in so doing give off gaseous decomposition products which implement the foaming operation. Physical propellants for foam injection molding are inert gases dissolved in the molten plastic material such as for example nitrogen or liquids which evaporate at low temperature. That means that the procedure is independent of the temperature decomposition range of chemically acting

propellants and it is also possible to foam plastic materials which are otherwise sensitive to resulting products from chemical propellants.

If the inert gases used such as for example nitrogen or CO_2 are put into a supercritical condition prior to the additive metering procedure, as is taught in US-A 4 473 655 and US-A 5 160 674, it is possible to produce a particularly uniformly distributed cell structure.

That supercritical condition of a gas affords the following advantages for the foaming process:

- liquid-like low compressibility for quantitatively accurate metering control, and
- high level of solubility and diffusion speed for uniform distribution and dissolution of the gas in the molten material.

The essential process steps of the microstructure foaming process are:

- homogenous fusion of the plastic material in the barrier screw portion,
- accurate quantitative metering control of the gas which has been put into the supercritical condition, by way of gas injectors, in the mass cylinder,
- fine distribution and dissolution of the gas in the molten polymer material in the screw mixing zone,
- formation of finely dispersed nucleation seeds due to the pressure drop at the beginning of the tool filling procedure,
- cell formation due to dissolved gas coming out of the molten material during the tool filling process, and
- cell growth due to the acting gas pressure in the cooling-down phase due to shrinkage compensation.

The essential advantages of the process are:

- the viscosity of the molten material is markedly reduced by virtue of use of the 'supercritical fluid' as a physical propellant. In extreme cases the injection pressure is reduced to 50% with the same mass temperature. Flow path-wall thickness ratios which can be achieved can also be markedly increased for plastic materials which are more difficult to cause to flow.

- Due to the improved flow capability and the post-pressure which acts internally by way of the gas pressure, the closing force required can be reduced, depending on the respective situation involved, to 60%.

- The internally acting gas pressure takes over the post-pressure function - collapse locations even at the end of the flow path can be avoided thereby. With a lower degree of foaming, there is the possibility of saving in terms of cooling time, in spite of poorer thermal conductivity. That is the case in particular when the amount of molten material which is otherwise still being introduced into the post-pressure phase determines the cooling time.

- With the same desired flow capability, the processing temperature can be markedly lowered and thus the cooling time can also be shortened.

- The lower filling pressure and the more uniform pressure distribution by virtue of the acting gas pressure, without partial post-pressure action, reduces distortion problems to a minimum.

Reference is made to Figure 1 to describe the apparatus which represents the state of the art and which is used at the present time for the described process. This involves an apparatus for admixing compressed gas to a molten plastic material with gas injectors which open into the mixing stage of a screw which also serves for plasticising the plastic material, comprising the following essential components:

1. gas supply from bottles, liquefied gas tank or gas-generating installation by decomposing air,

2. gas processing installation with compressor and quantitative gas metering unit,

3. mass cylinder,

4. screw with plasticising portion and downstream-connected propellant mixing stage,

5. gas injectors,

6. mass pressure sensor,

7. air-cooled heating belts in the mixing stage,

8. closure nozzle,

9. machine control with process-specific software.

The crucial consideration for the foaming procedure is uniform quantitative gas metering into the molten material by way of the gas injectors. In the known process quantitative gas metering is effected by way of measuring cells and quantitative regulating valves in the gas processing installation 2. In that case the gas has to be passed to the gas injectors 5 by way of relatively long hose and/or pipe connections. Metering inaccuracies occur by virtue of compressibility and pressure losses in the conduits. In addition there is no feedback between the molten material conveyor output or capacity of the plasticising and mixing screw and the quantitative gas metering unit in the gas processing installation. The same amount of gas is always meteredly added when conveyor output differences occur in the screw, in relation to time. Different amounts of gas in an element of volume of the molten material being considered and partially different degrees of foaming in the component are the consequence thereof.

The invention is based on the notion that, after reaching the supercritical condition, the gas behaves substantially like a liquid and its density within the limits of the pressure differences occurring can be viewed to a good degree of approximation as being constant. That permits accurately metered addition of gas using simple structural means, insofar as it is provided that disposed immediately upstream of the gas injectors is a metering piston whose speed of travel is correspondingly greater, the greater the speed of return travel of the screw in the plasticising procedure.

An embodiment of an apparatus of that kind is described hereinafter with reference to Figure 2.

The quantitative gas metering operation is effected by way of a pressure transmitter or booster 10 driven by a hydraulic assembly 11. The pressure booster is mounted in the immediate proximity of the gas injectors 5 on the mass cylinder 3 in order to have very short conduit lengths and thus also very small dead volumes. The supply of gas (for example N_2 or CO_2) to the pressure booster 10 is effected by way of a gas pre-compressor unit 12 or directly from gas bottles, liquid tanks or air decomposition installations. The pressure booster can also perform the gas-

compressing function. In that way it is possible to omit an additional gas pre-compressor unit.

Operating procedure:

- the gas intake flow valve 13 at the pressure booster 10 is opened and gas flows into the pressure booster chamber. The pressure booster is pushed back by the inflowing gas or also with hydraulic assistance and in so doing the oil on the hydraulic side is expelled from the piston to the tank.

- When the limit position of the piston is reached the gas intake valve 13 is closed.

- Compression of the gas in the pressure booster 10 is effected by a hydraulically controlled or regulated advance movement until a gas pressure which is set at the machine control 9 is reached. Measurement of the current gas pressure is effected by way of the gas pressure sensor 14.

- With the beginning of the plasticising and molten material metering procedure by starting the rotary movement of the screw, the first gas injector 5 is opened and, in dependence on the measured screw return movement speed, the piston forward travel speed of the pressure booster 10 is regulated by way of a regulating valve 15 in order to urge an amount of gas which is preset at the control means, into the mass cylinder of the injection molding machine.

- When a given screw position is reached, the next gas injector 5 is opened. The prevailing molten material pressure in the mass cylinder is measured in the proximity of the gas injectors, by way of the pressure sensor 6. The measured molten material pressure for transportation of the molten material through the gas mixing zone and for overcoming the dynamic pressure (set counterpressure for the rearward movement of the screw) supplies the necessary information about the required level of pressure for pre-compression of the gas. That provides that the gas no longer has to be heavily compressed in the pressure booster 10 before gas is introduced in a metered fashion against the prevailing molten material pressure (for example 200 bars).

- The gas pressure which is measured in the pressure booster and the measured molten material pressure can be used for monitoring the

molten material and gas metering process. The process graphics in the machine control 9 detects the pressure patterns and monitors the reproduction accuracy of the metering process over a predetermined tolerance range.

- The amount of gas introduced under pressure is ascertained by way of a gas density function in dependence on pressure and temperature for each molten material metering cycle and monitored on the basis of adjustable limit values by way of the machine control 9. The pressure booster is equipped with a travel measuring system 16 for that purpose.

- With the termination of the molten material metering process, the last gas injector is closed and the molten material is held under a given pressure in order to avoid premature foaming-up thereof.

With the gas booster structure it is also possible to supply a plurality of injection molding machines without using a gas processing unit at each injection molding machine, by way of gas ring conduits.